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Production of Arthropod Pests and Vectors in Coal Strip Mine Ponds

Tennessee Valley Authority, Chattanooga

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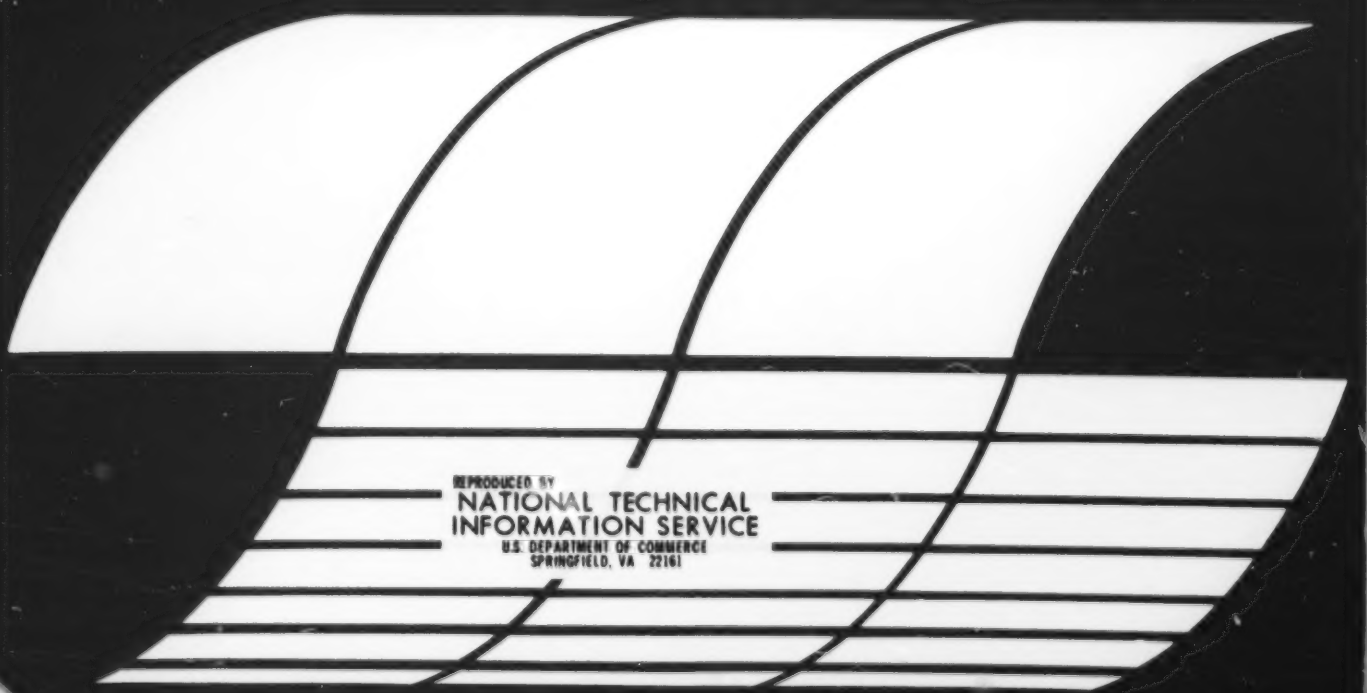
Production of Arthropod Pests and Vectors in Coal Strip Mine Ponds

Interagency Energy/Environment R&D Program Report



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The objective of this study was to determine what species of medically important arthropods, particularly mosquitoes, are breeding in coal strip mine ponds, to what extent, and whether these breeding sites will serve as a focus of annoyance or a potential outbreak center of arthropod-borne diseases to surrounding communities. Pond age was compared with physical and chemical characteristics of the water and associated vegetation communities. Various sampling techniques were used to determine the composition and density of all life stages of the aquatic insect fauna.

Results showed that mosquito production did occur in coal strip mine ponds, becoming evident during the second season after pond formation. The degree of mosquito production and the diversity of species composition increased as the ponds aged. Although mosquito breeding occurred in all but the 1-year-old ponds, production was sparse and restricted to narrow vegetated areas along shallow, marginal shelves. The level of mosquito activity detected during this 3-year survey was not sufficient to cause severe annoyance to surrounding communities. Mosquito larvae dipping records in early March showed that strip mine ponds could provide many favorable sites where overwintering females of An. punctipennis and An. quadrimaculatus could deposit eggs for the first spring brood.

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PRODUCTION OF ARTHROPOD PESTS AND VECTORS IN COAL STRIP MINE PONDS

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ABSTRACT

The objective of this study was to determine the species of aquatic arthropod pests, mainly mosquitoes, that were breeding in abandoned coal strip mine ponds, their population densities, and whether these breeding sites would serve as foci for annoyance to surrounding human populations.

Nine study ponds were selected in Marion County, Alabama, on the basis of age since formation, with a total of three test ponds in each of three age categories: 1-year-old, 5-year-old, and 10-year-old. These ponds have been observed for three successive years; thus, all ponds are now three years older than when observations first began. The six oldest ponds will be observed for two more years and the three youngest ponds will be observed for one more year. At the end of the studies, six ponds will have aged five years since the beginning of observations, and three will have aged four years.

Mosquito larvae of four genera including eight species were collected from the strip mine study area from 1976 through 1978. Anopheles punctipennis, Anopheles quadrimaculatus, and Culex erraticus were the most prevalent species in ponds formed five or more years ago. Dipping records showed that a small number of the floodwater mosquito larva, Psorophora columbiae, occurred in the ponds. Although mosquitoes did not occur in the 1-year-old ponds, they were present in small numbers in the 2-year-old ponds. Mosquito species collected from 2-year-old ponds included An. punctipennis, C. erraticus, and Culex territans. Four species of floodwater mosquito ova, Aedes vexans, Aedes sollicitans, P. columbiae, and Psorophora cyanescens, were found in soil samples taken from selected transects along pond margins. Ae. vexans was the most abundant floodwater mosquito ova in the ponds. The largest number of positive samples for mosquito ova were from ponds 10 years of age and older. No floodwater mosquito ova were found in soil samples taken from ponds three years old or younger. Only two species of mosquitoes found in the strip mine ponds, C. territans and Uranotaenia sapphirina, have little or no economic or medical importance.

Mosquito larvae in all the ponds were associated primarily with areas colonized by variable-leaf pondweed (Potamogeton diversifolius), woolgrass (Scirpus cyperinus), and cattail (Typha latifolia). In summary, data showed an unexpected diversity of mosquito species composition, but breeding in all the ponds was light.

The total number of insect taxa collected in benthic and surface samples in 1-, 2-, and 3-year-old ponds was 24, 43, and 54, respectively. The largest group of insects, both in species composition and numbers collected, was the Chironomidae, or "nonbiting midges." Two genera of insects of public health importance, Palpomyia and Chrysops, were found in small numbers in the 1-, 2-, and 3-year-old ponds.

Benthic and surface samples in the 5-, 6-, and 7-year-old ponds yielded 49, 55, and 62 aquatic insect species, respectively. Three groups of insects of medical importance--Palpomyia, Chrysops, and Tabanus--were found in dredge samples from the 5-, 6-, and 7-year-old ponds.

Results from benthic and surface samples in the 10-, 11-, and 12-year-old ponds showed this age group to have the greatest insect species diversity. Data from the 10-, 11-, and 12-year-old ponds showed 42, 58, and 66 insect taxa, respectively. Midge larvae, Procladius, were the most abundant immature insects collected. A small number of larvae of the biting midge, Palpomyia, and Chrysops larvae were found in the 10-, 11- and 12-year-old ponds. The number of insect taxa of medical importance detected by dredge and net sampling methods during the 3-year survey of the nine study ponds was sparse, both qualitatively and quantitatively.

A total of 23 adult specimens, representing seven species of the family Tabanidae (horse flies and deer flies), were collected from inside a parked sedan car located near the strip mine study ponds.

Field plant surveys on the nine study ponds yielded a total of 69 macrophytes. The number of vascular species increased as the age of the ponds increased, reflecting invasion by early successional dominants. Two submersed aquatic macrophytes (P. diversifolius and Potamogeton pusillus), both of which provide favorable mosquito habitat, became established in the 2-year-old ponds. The most commonly occurring plants found in all the ponds were the pondweeds (P. diversifolius), cattail (Typha latifolia), woolgrass (Scirpus cyperinus), rushes (Juncus spp.), sedges (Eleocharis spp.), smartweeds (Polygonum spp.), panic grasses (Panicum spp.), beggar ticks (Bidens frondosa), and Eupatorium spp. The neighboring terrestrial species were mostly "weedy" taxa commonly found on disturbed sites.

Water chemistry data obtained during the 3-year study showed no significant change in the pH of the water in the nine study ponds. The pH of the ponds had a seasonal range of 6.0 to 8.7 in the 1- to 3-year-old ponds, 5.7 to 9.0 in the 5- to 7-year-old ponds, and 5.0 to 8.6 in the 10- to 12-year-old ponds. The dissolved oxygen content of the water in the ponds varied widely with seasonal changes, ranging from 4.1 to 14.1 ppm. Water temperatures did not vary significantly between the nine study ponds. Water conductivity determinations in the 11- and 12-year-old ponds were significantly lower than determinations in the other ponds. Water levels in the 5-, 6-, and 7-year-old ponds were more variable throughout the study period.

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LIST OF ABBREVIATIONS AND SYMBOLS

ppm	--parts per million
Y.S.I.	--Yellow Springs Instrument
S-C-T	--Salinity-conductivity-temperature
km	--kilometers
mmhos/cm	--measurement of electrical conductance when measured between opposite faces of a 1-cm cube
°C	--degrees Celsius
I	--Infrequent
C	--Common
A	--Abundant
ha	--hectares
m	--meter
cm	--centimeters

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SECTION 1

INTRODUCTION

Surface mining for coal is carried out extensively in several counties in north Alabama, resulting in formation of numerous permanent to semipermanent ponds. The ponds included in this study are located near the eastern border of Marion County in the vicinity of New River and in the community of Gold Mine, Alabama. An estimated 2428 to 2833 ha of surface coal mines exist in Marion County. Demand for coal has been greatly accelerated by the recent energy crisis; this demand, coupled with increases in the price of coal and the availability of larger and more powerful earth-moving equipment, has resulted in the reopening and reworking of many abandoned surface mines that could not be operated economically a few years ago. To support the demand for coal, efforts have been increased to obtain property containing coal suitable for strip mining; these efforts have resulted in the encroachment of mining operations upon many rural towns with moderate population densities. Extensive tracts of barren countryside, containing many small lakes and ponds, often result from these strip mining operations. These bodies of water may vary in size from a few hundred square meters to several hectares. Water depths may vary from 2 to 15 m, depending on the depth of the final cut. The water level in the ponds may fluctuate one to three times in a growing season, and the amplitude in fluctuation may be from 1 to 2 m during certain dry seasons.

For centuries man has fought insects as pests and vectors of disease. Mosquitoes, probably the best-known group of insect pests, have adapted themselves to various climates and are found in all the land areas of the world, wherever pools of water are available for a few days or longer for breeding and where sufficient numbers of host organisms are present. Mosquitoes have probably had a greater influence on human health and welfare throughout the world than any other group of insects.

The objective of this study was to determine what species of medically important arthropods, particularly mosquitoes, are breeding in coal strip mine ponds, to what extent, and whether these breeding sites will serve as a focus of annoyance or a potential outbreak center of arthropod-borne diseases to surrounding communities. Emphasis of study involves a comparison of pond age with physical and chemical characteristics of the water and associated vegetation communities. The survey uses various sampling techniques to determine the composition and density of all life stages of the aquatic insect fauna.

Of numerous ponds that were field-inspected, nine study ponds were selected by age (time since formation). Three ponds in each of three age categories (1 year, 5 years, and 10 years) were selected for study when the project was initiated in 1976. These ponds have been observed for three successive years so that now all ponds are three years older

than when the observations first began. Observations will continue for two more years on the six oldest ponds and for one more year on the three youngest ponds; at the end of the studies, six ponds will have aged five years since the onset of observations, and three will have aged four years. These nine study ponds are shown on an aerial photograph (Figure 1). The study has been initially designed to progress for five consecutive years, so that the data obtained would include 14 consecutive years of natural ecological succession. The project was designed to show temporal changes in species composition and relative abundance of aquatic fauna and flora.

Figure 1. Aerial photograph of strip mine area, showing locations of the mine study ponds.

SECTION 2

CONCLUSIONS

Results from this study showed that mosquito production did occur in coal strip mine ponds, becoming evident during the second season after pond formation. The degree of mosquito production and the diversity of species composition increased as the ponds aged. Although mosquito breeding occurred in all but the 1-year-old ponds, production was sparse and restricted to narrow vegetated areas along shallow, marginal shelves. The level of mosquito activity detected during this 3-year survey was not sufficient to cause severe annoyance to surrounding communities. Mosquito larvae dipping records in early March showed that strip mine ponds could provide many favorable sites where overwintering females of An. punctipennis and An. quadrimaculatus could deposit eggs for the first spring brood.

Data from benthic and surface sampling reflected a wide variety of aquatic insect taxa in ponds of all age categories. However, the 12-year-old ponds contained the largest number with a total of 68 species. There was a paucity of insects of medical importance found in the nine study ponds; only three genera of public health importance were collected, which consisted of Palpomyia, Chrysops, and Tabanus. Based on the small numbers of Palpomyia, Chrysops, and Tabanus collected from all pond age categories no public health problem is anticipated.

Surveys of the vascular plants in each of the nine ponds yielded a total of 69 species. The number of macrophyte taxa increased with the age of the ponds. Two submersed aquatic species (P. diversifolius and P. pusillus), both of which provide favorable mosquito habitat, first became established in the 2-year-old ponds.

Cursory observations of abandoned coal strip mine ponds in north Alabama indicate that efforts should be made to develop the ponds as suitable habitats for waterfowl and other wildlife.

Water chemistry of all ponds studied showed very favorable conditions for supporting various aquatic fauna and flora.

SECTION 3

EXPERIMENTAL PROCEDURES

Description of the Study Area

The slope of the spoil bank around two of the ponds that were one year old at the beginning of the study was moderately steep and short. The other 1-year-old pond was located along a final cut and was enclosed by a 12- to 15-m abrupt spoil bank on one side and a high wall on the other. The maximum water depth in the ponds was about 5 m, and the sampling stations were located along the shallow margins. The water in the ponds was replenished from rainfall runoff and subterranean seepage. The slopes around the ponds were generally barren, except for sparse pioneer colonies of species such as pokeweed (Phytolacca americana). The margins around the ponds were abrupt, except for those areas in which small alluvial deltas had been formed by siltation. The most recent ponds were formed in the late spring of 1975.

All the ponds that were five years old at the beginning of the study (5-year-old ponds) occurred along the base of high walls that ranged in height from 9 to 12 m. The spoil was deposited in undulating ridges, which averaged about 5 m in height. Except for access roads extending into the pits, the slopes of the pond margins were very steep. The average water depth in these ponds was about 3 m. The water depth at the sampling stations ranged from 30 to 90 cm. Sericea (Lespedeza cuneata) formed a dense colony on the spoil banks around two of the ponds, whereas the other spoil area contained mixed colonies of L. cuneata and P. americana with some bare soil. The pond water collects from rainfall and subterranean seepage. The 5-year-old ponds were formed in the fall and winter of 1970.

The original 10-year-old study ponds occurred in remote areas where the coal had been covered by a shallow overburden. The ponds were enclosed by high walls and spoil banks, ranging in height from about 6 to 9 m. The dominant herbaceous vegetation on the spoil banks consisted of four genera: Lespedeza, Rubus, Andropogon, and Phytolacca. Saplings of sweetgum (Liquidambar styraciflua), loblolly pine (Pinus taeda), black willow (Salix nigra), and sumac (Rhus sp.) were present on the spoil slopes. The average water depth was about 3 m. Water depth at the sampling stations ranged from 30 to 90 cm. Except for the shallow areas along abandoned access roads into the strip pits, the pond margins were very abrupt. Water levels in the ponds were maintained by subterranean seepage and rainfall. The coal was mined from these strip pits in early 1965.

The topography in the Gold Mine area of Marion County is predominantly hilly with steep slopes. The soil is predominantly dark gray sand-loam, with soil pH ranging from slightly acid to moderately alkaline. The fertility is moderate and the soil is low in organic content. Percolation is moderately rapid, and the available water storage capacity is medium to

low. The plant root zone is very shallow due to the abundance of consolidated sandstone outcrops in the strip-mined areas. Erosion is severe due to previous land use practices and especially severe where strip mining operations have been conducted.

Materials and Methods

In each of the nine study ponds three sampling stations were established, either in the vicinity of emergent aquatic vegetation or in shallow marginal areas where emergent or submersed vegetation was likely to ecize. Monthly surveys were conducted from April to October to determine the species composition and relative abundance of aquatic arthropods in each pond.

Mosquito larvae were sampled by using the standard dipper technique. Fifteen dips were taken near each sampling station in the study ponds. The number of mosquito larvae collected per dip and the stage of development of each were recorded, and a representative sample was collected for species identification. To determine the presence and species composition of floodwater mosquito ova, soil samples (15- by 15- by 2.5-cm) were collected from likely oviposition sites along established transect lines in each study pond. Transects were established to coincide with anticipated habitat and flooding contours within each pond. Each sample was processed through a series of sieves, consisting of 40-, 60-, and 100-mesh sizes, and through a flotation process, which separated the ova from the soil (Horsfall 1956). The mosquito ova from each soil sample were counted and identified to species. All soil samples were collected in the late fall.

Bottom samples for benthic organisms were taken with an Ekman dredge. About 900 cm2 of substrate, consisting of four 15- by 15-cm samples, were collected at each of the three stations in each pond. The sample was washed through a 40-mesh sieve, and the remaining benthic organisms were recovered and preserved in hood solution.

Water surface sampling for aquatic invertebrates was accomplished by using a fine mesh aquatic dip net with a 30-cm opening. A sample consisted of sweeping the net through about two linear meters of water surface. Three samples were taken at each station.

Surveys were conducted in May and September to inventory the existing plant species and to document their relative density and frequency in each study pond. Vegetation was surveyed by visual inspection and enumeration of areal cover along segmented transects. Physical and chemical parameters of each pond were measured with portable instruments. The pH of the water was determined with an Orion specific ion meter (model 407A). The dissolved oxygen readings in the water were taken with a Y.S.I. model 54A oxygen meter. The oxygen determinations were made between 9 a.m. and 3 p.m. Water temperatures were recorded using a pocket thermometer. A Y.S.I. model 33 S-C-T meter was used to measure salinity and conductivity. Due to difficulties in obtaining an instrument for determining conductivity and salinity of water in the ponds, these measurements were not started until June 1977. All readings were taken at a depth of about 5 cm.

A staff gauge was placed in each study pond to detect water level deviations from a baseline level. The gauge was constructed of a 1.8-m (2.5- by 10-cm) board divided into 3-cm increments from a zero point at the center of the staff. Water-level readings were made in conjunction with each monthly insect survey. A photographic reference point was established for each pond, and sequential photographs were made from these points to provide a visual record of the physical changes occurring during the course of the study.

SECTION 4

RESULTS AND DISCUSSION

Mosquito Larval Sampling

Results obtained from larval sampling for mosquitoes in the nine study ponds in 1976, 1977, and 1978 are given in Table 1. The average number of larvae per dip listed for each age category is a composite record for three study ponds in each age classification. The most significant data relate to species composition and show that eight species representing four genera of mosquitoes were collected during the 1976, 1977, and 1978 growing seasons. Six of the mosquito species collected will bite man, and all have a flight range of about 2 km. However, marked female specimens of Psorophora columbiae have been retrieved by light traps at a distance of 9.7 km (Horsfall 1942). Culex territans and Uranotaenia sapphirina, two of the eight species collected, are of no known economic or medical importance in the Tennessee Valley.

Dipping records indicated that the 5-, 6-, and 7-year-old ponds were the most productive for mosquitoes, both quantitatively and qualitatively. Seven species were represented in the 5- and 7-year-old pond collections, respectively. Anopheles quadrimaculatus, the malaria vector, was found in significant numbers in ponds that have been established for five or more years. In general, An. punctipennis and C. erraticus were the most prevalent species present in all the ponds. Mosquito production was not detected until ponds were two years old or older. Several specimens of An. punctipennis and C. erraticus larvae were collected from the 2-year-old ponds. Limited production of An. punctipennis and C. erraticus was recorded in the 3-year-old ponds. C. erraticus egg rafts were also found attached to leaf margins of floating leaves of variable-leaf pondweed (Potamogeton diversifolius) in a 3-year-old pond.

Only one species of the floodwater or rainpool group of mosquitoes was collected from the nine study ponds. One larval specimen of P. columbiae was found in a 7-year-old pond. However, extensive rains in August and September 1977 flooded many semi-aquatic depressions, colonized by Typha latifolia, throughout the strip mine study area and produced a brood of this floodwater mosquito. Larval sampling yielded an average of three larvae per dip in the flooded depressions. P. columbiae deposits its eggs on the damp soil in depressions that are intermittently flooded. Usually, large numbers of larvae are produced at a hatching, and adults may appear as early as six days after flooding. This species causes serious annoyance to man and livestock and has also been incriminated in the transmission of equine encephalitis and dog heartworm disease. Several biting adult specimens of P. columbiae were collected near the strip mine area.

TABLE 1. SUMMARY OF MOSQUITO PRODUCTION, BASED ON AVERAGE NUMBER OF LARVAE PER DIP IN COAL STRIP MINE PONDS IN MARION COUNTY, ALABAMA, APRIL - OCTOBER 1976, 1977, and 1978

1976

Species	April			May			June			July			August			September			October			Total		
	Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)		
	1[a]	5[a]	10[a]	1	5	10	1	5	10	1	5	10	1	5	10	1	5	10	1	5	10	1	5	10
Anopheles crucians	-	0.00	0.00	-	0.00	0.00	-	0.03	0.00	-	0.17	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.03	0.00
Anopheles punctipennis	-	0.07	0.04	-	0.04	0.04	-	0.20	0.13	-	0.81	0.43	-	0.04	0.00	-	0.01	0.17	-	0.00	0.00	-	0.17	0.13
Anopheles quadrimaculatus	-	0.00	0.00	-	0.02	0.00	-	0.14	0.02	-	0.48	0.30	-	0.04	0.00	-	0.09	0.02	-	0.00	0.00	-	0.11	0.06
Culex erraticus	-	0.00	0.00	-	0.01	0.01	-	0.02	0.07	-	1.43	1.92	-	0.08	0.00	-	0.92	0.66	-	0.00	0.00	-	0.31	0.46
Culex restuans	-	0.02	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.01	0.00
Culex territans	-	0.01	0.00	-	0.00	0.00	-	0.00	0.07	-	1.94	0.00	-	0.00	0.24	-	0.01	0.01	-	0.00	0.00	-	0.26	0.03
Uranotaenia sapphirina	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.02	0.00	-	0.00	0.00	-	0.00	0.00	-	0.00	0.00	-	0.01	0.00

1977

Species	April			May			June			July			August			September			October			Total		
	Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)		
	2[a]	6[a]	11[a]	2	6	11	2	6	11	2	6	11	2	6	11	2	6	11	2	6	11	2	6	11
Anopheles crucians	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Anopheles punctipennis	0.00	0.04	0.02	0.00	0.37	0.01	0.00	0.07	0.22	0.00	0.06	0.08	0.05	0.04	0.15	0.00	0.20	0.42	0.00	0.39	0.59	0.01	0.20	0.21
Anopheles quadrimaculatus	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.07	0.28	0.00	0.13	0.30	0.00	0.00	0.01	0.00	0.40	0.11	0.00	0.00	0.00	0.00	0.06	0.08
Culex erraticus	0.00	0.00	0.00	0.00	0.06	0.01	0.00	2.04	0.97	0.00	0.69	2.00	0.00	12.20	2.56	0.02	1.77	0.56	0.00	0.01	0.06	0.01	1.45	0.71
Culex territans	0.00	0.00	0.00	0.00	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.00	0.21	0.00	0.00	0.00	0.01	0.00	0.08

1978

Species	April			May			June			July			August			September			October			Total		
	Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)			Pond age (y)		
	3[a]	7[a]	12[a]	3	7	12	3	7	12	3	7	12	3	7	12	3	7	12	3	7	12	3	7	12
Anopheles crucians	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.01
Anopheles punctipennis	0.00	0.00	0.10	0.00	0.01	0.06	0.00	0.12	0.00	0.00	0.18	0.30	0.00	0.14	0.26	0.00	0.07	0.23	0.00	0.40	0.65	0.00	0.09	0.22
Anopheles quadrimaculatus	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.03	0.05	0.00	0.23	0.56	0.00	0.04	0.33	0.00	0.09	0.14	0.00	0.20	0.02	0.00	0.07	0.16
Culex erraticus	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.12	0.06	0.00	1.61	0.30	0.11	1.99	1.38	0.04	5.96	7.57	0.00	0.10	0.61	0.07	1.15	1.11
Culex restuans	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Culex territans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Psorophora columbiae	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00

[a]Average of three ponds.

Heavy rainfall in February 1977 flooded vegetated marginal areas of the study ponds. Supplemental larval dipping records in early March showed mosquito production of An. punctipennis, An. quadrimaculatus, C. restuans, and C. territans in areas colonized by T. latifolia in the 6- and 11-year-old ponds. Strip mine ponds could serve as a major habitat for the first spring brood of permanent pool species of mosquitoes.

Mosquito larval occurrence in all the ponds was primarily associated with areas colonized by aquatic macrophytes such as variable-leaf pondweed (P. diversifolius), woolgrass (Scirpus cyperinus), and cattail (T. latifolia). The heaviest mosquito production occurred during July through September.

Although data in Table 1 indicate significant mosquito production in strip mine ponds that have been formed for five or more years, the mosquito habitat occurred only around the periphery of the ponds and consisted of only a small percentage of the total water surface area. Most of the mosquito habitat was located in narrow vegetated areas along shallow, marginal shelves. Because of the abrupt pond margins and the small amount of vegetation in the ponds, the mosquito breeding potential, especially for permanent pool species, was limited in most of the ponds. As a general rule, the intensity of mosquito production of permanent pool species is directly related to the amount of plant life and flotage breaking the water surface (Bishop 1947). However, in those ponds where the water level recedes and extensive shoreline areas are dewatered, floodwater species of mosquitoes could become a problem.

Mosquito Ova Sampling

Table 2 summarizes data from soil samples collected to determine the extent and successional changes of floodwater mosquito populations along strip mine pond margins; oviposition data are used as an indicator. The total number of soil samples collected from the different pond age categories was governed by the size of the dewatered pond margin, with the maximum high water level serving as the upper limit. The data in Table 2 show that most of the floodwater mosquito ova collected were from the 10-, 11-, and 12-year-old ponds. Of the total number of floodwater mosquito ova collected, about 90 percent were from this age category, and 10 percent of the ova were from the 5-, 6-, and 7-year-old ponds. No floodwater mosquito ova were found in soil samples collected from the 1-, 2-, and 3-year-old ponds. Floodwater mosquito species present in the nine study ponds, as indicated by soil sampling data collected over a period of three years, were Aedes vexans, Ae. sollicitans, P. columbiae, and P. cyanescens. Data from soil samples showed Ae. vexans was the predominant floodwater mosquito species in the study ponds. Results from the soil sampling program showed only three ova of Ae. sollicitans present, which were found in the 5- and 10-year-old pond categories. Ova of P. columbiae and P. cyanescens were found in sparse numbers in the 12-year-old ponds. No floodwater mosquito ova were recovered in soil samples from the 7-year-old ponds. Due to high water level in the ponds at the time soil samples were collected from the

TABLE 2. SPECIES AND NUMBER OF FLOODWATER MOSQUITO OVA COLLECTED FROM SOIL SAMPLES TAKEN IN COAL STRIP MINE PONDS, MARION COUNTY, ALABAMA, APRIL - OCTOBER 1976, 1977, AND 1978

November 1976			
	From ponds aged		
	1 y[a]	5 y[a]	10 y[a]
Samples taken	22	53	42
Samples positive for mosquito ova	0	3	14
Percent positive samples	0.0	5.7	33.3
Aedes sollicitans ova	0	1	2
Aedes vexans ova	0	3	98

November 1977			
	From ponds aged		
	2 y[a]	6 y[a]	11 y[a]
Samples taken	15	39	40
Samples positive for mosquito ova	0	3	10
Percent positive samples	0.0	7.7	25.0
Aedes vexans ova	0	13	39

November 1978			
	From ponds aged		
	3 y[a]	7 y[a]	12 y[a]
Samples taken	25	32	46
Samples positive for mosquito ova	0	0	5
Percent positive samples	0.0	0.0	10.8
Aedes vexans ova	0	0	6
Psorophora columbiae ova	0	0	2
Psorophora cyanescens ova	0	0	1

[a]Average of 3 replicates.

2-, 6-, and 11-year-old ponds, the number of samples collected and the number of sampling transects evaluated were limited in several study ponds, and this limitation may have influenced the collection of mosquito ova. Positive soil samples in all pond age categories were collected in association with the following vegetation: T. latifolia, Salix nigra, Scirpus cyperinus, Aster pilosus, and Andropogon virginicus.

Adult females of Ae. vexans, Ae. sollicitans, P. columbiae, and P. cyanescens all feed readily on man, and being strong fliers, they often migrate in large numbers from their breeding sites into populated areas in search of a blood meal. The females of Ae. vexans, P. columbiae, and P. cyanescens generally deposit their ova on the damp soil in vegetated depressions that are intermittently flooded. These three floodwater mosquito species are widely distributed throughout the Tennessee Valley and are three of the most important pest species. The females of Ae. sollicitans normally deposit their ova on the soil in the tidewater salt marshes containing brackish or saline water, which are subject to intermittent flooding. Other oviposition sites may include pools of effluents from certain factories, pools around oil wells, and coal mine ponds (Horsfall 1955).

The paucity of floodwater mosquito production in most of the coal strip mine study ponds is probably due in part to the frequent silting of pond margins caused by extensive erosion from barren spoil areas after heavy rains. Mosquito ova are covered by layers of silt during the winter, and mosquito larvae from the enclosed ova cannot emerge from beneath the soil when the habitat is inundated the following spring. The lack of floodwater mosquito production along pond margins may also be due to the sparse vegetation, surface detritus cover, and xeric soil, which make these areas unattractive to ovipositing females.

Benthic and Surface Sampling for Aquatic Insects

The insect taxa from bottom and surface samples found in the strip mine ponds for three years of the planned 5-year-succession study are listed in Table 3. The dredge and net samples yielded about the same number of insect taxa, but the species composition and the number of specimens collected differed significantly, especially in the aquatic Diptera. About 85 percent of all the insect genera collected are predacious, either as adults or as immatures.

The number of insect taxa in the 1-, 2-, and 3-year-old ponds detected by dredge and net sampling methods was 24, 43, and 54 species, respectively. The most significant increase, both in species composition and in the number of specimens collected, was in the Chironomidae, or "nonbiting midges." By comparison, data from bottom samples yielded the following Chironomidae counts: 1-year-old ponds--9 species, total of 21 specimens; 2-year-old ponds--14 species, total of 147 specimens; and 3-year-old ponds--20 species, total of 433 specimens. Larvae of the mayfly, Hexagenia munda elegans, were found in the 2-year-old ponds, the youngest ponds in which they have occurred. This species was also found

TABLE 3. INSECT TAXA TAKEN FROM COAL STRIP MINE PONDS IN MARION COUNTY, ALABAMA, APRIL - OCTOBER 1976, 1977, AND 1978[a]

Species composition	From ponds aged								
	Years			Years			Years		
	1	2	3	5	6	7	10	11	12
Ephemeroptera									
Baetidae									
Callibaetis	I	C	I	C	C	C	I	I	I
Cloeon				I					
Caenidae									
Caenis			I			C		I	
Ephemeridae									
Hexagenia munda elegans		C	C	A	C	I	A	A	A
Odonata									
Aeshnidae									
Anax junius				I	C			C	I
Anax longipes		I		I	I		I	I	I
Basiaeschna janata					I				
Coenagrionidae		I							
Anomalagrion hastatum		I		I	I	I		I	
Argia fumipennis					I	I	I	I	I
Argia sp.			I			I			
Enallagma aspersum		I	I	C	C		C	C	C
Enallagma basidens					I	A		I	
Enallagma civile			I	I		I			
Enallagma doubledayi					I				
Enallagma signatum (group)				I					
Enallagma sp.			C			C			C
Ischnura posita			C	C		C	I	I	C
Corduliidae									
Epitheca cynosura					I			C	
Gomphidae									
Dromogomphus spinosus	I	C		I	I	C			
Gomphus exilis	C	C	C	C	C	I	A	C	I
Gomphus sp.			C			C			I
Lestidae									
Archilestes grandis								I	
Lestes disjunctus					I	I	I		I
Libellulidae						I			
Celithemis elisa					A			I	I
Erythemis simplicicollis							I		I
Libellula cyanea						I	I		
Libellula sp.				I					I
Pachydiplax longipennis	I		I	I		C			
Pantala flavescens	I	C	I			I		C	C
Planthemis lydia							I		
Sympetrum vicinum								I	
Tramea sp.				I		C			I
Macromiidae									
Didymops transversa		C	I	I	C	C		C	I

TABLE 3 (continued)

Species composition	From ponds aged								
	Years			Years			Years		
	1	2	3	5	6	7	10	11	12
Orthoptera									
Tridactylidae									
Tridactylus					I				
Hemiptera									
Belostomatidae									
Belostoma				I	I	I	I		
Corixidae			I						I
Hesperocorixa		I						I	I
Sigara		I	I		I		I	C	C
Gerridae									
Gerris		I	I	C	I	I		I	I
Limnogonus				C	I			I	
Rheumatobates				I	I				I
Trepobates		I	A	A	A	A	C	A	A
Hydrometridae									
Hydrometra		I	I	I				I	I
Mesoveliidae									
Mesovelia			C	C	I	C	I	I	I
Naucoridae									
Pelocoris				I	I	I	C	I	
Nepidae									
Ranatra	I	I	I	C		I		C	C
Notonectidae									
Buenoa	I	A	I	C			A	A	A
Notonecta	A	A	I	A	I		C	C	C
Veliidae									
Microvelia			I	I		A	I		
Trichoptera									
Polycentropodidae									
Polycentropus			I		C	C			
Coleoptera									
Dytiscidae									
Agabus disinegratus			I	I			I		I
Agabus (larvae)				I					
Copelatus glyphicus							I		
Coptotomus interrogatus		C	I	C	C	I	I	C	A
Deronectes									I
Hydroporinae (genus unidentified)									I
Hydroporus rufilabris							C	I	I
Hydroporus undulatus	I	I		A	A		C	I	I
Hydroporus sp.						I			
Hygrotus		I							
Laccophilus maculosus	A	A	C	A	C	I	C	A	A
Laccophilus proximus				I					
Thermonectus		I							

TABLE 3 (continued)

Species composition	From ponds aged: 1 Year	2 Years	3 Years	5 Years	6 Years	7 Years	10 Years	11 Years	12 Years
Elmidae						I			
Gyrinidae									
Dineutus	A	A	A	C	A	A	A	A	A
Gyrinus		C	I		I			I	I
Haliplidae									
Peltodytes					C	C	I	I	I
Hydrophilidae									
Berosus infuscatus	I			I		I			
Berosus nr. aculeatus			I	C	A	I	C	C	C
Cymbiodyta blanchardi							I		
Helochares maculicollis							I		
Helophorus								I	
Paracymus (subcupreus group)							I	I	
Tropisternus lateralis		I		C	I	I	I	I	C
Noteridae									
Hydrocanthus						I			
Megaloptera									
Sialidae									
Sialis	I	I	C	C	C	A		C	A
Diptera									
Ceratopogonidae			C			C			I
Palpomyia	C	A	A	A	A	A	I	A	C
Chaoboridae									
Chaoborus			I					I	I
Corethrella					I				
Eucorethra					I				
Chironomidae			I			C			C
Ablabesmyia annulata								I	
Ablabesmyia sp.	I	A	A	I	A	A	I	A	A
Chironomus		I	C	I	A	A	C	A	A
Cladotanytarsus	I	C	A		I	I		I	C
Coelotanypus						I			A
Clinotanypus			I			I	I	C	C
Cricotopus remus				I					I
Cricotopus sp.		C	C		I	I		I	I
Cryptochironomus sp.	I	C	I		I	I		I	I
Cryptocladopelma								C	
Cryptotendipes sp. 1		I						I	
Cryptotendipes sp. 2					I			I	
Dicrotendipes			I		I	A	I	I	C
Einfeldia								C	I
Endochironomus nigricans	I	C	C	C	C	A	C		C
Goeldichironomus holoprasinus		I							
Harnischia		I	I						
Miscropsectra						C			
Microtendipes					I				
Pagastiella		I		I	I	I			

TABLE 3 (continued)

Species composition	From ponds aged								
	Years			Years			Years		
	1	2	3	5	6	7	10	11	12
Paratendipes						I			I
Polypedilum	I	A	A	I	A	A	I	A	A
Procladius	I	A	A	A	A	A	A	A	A
Rheotanytarsus			I			I			I
Stictochironomus devinctus	I	A				A			C
Tanypus						C		I	I
Tanytarsus	I	I	C	I	C	A			A
Orthocladiinae (genus unidentified)	I	I	I			I			A
Orthocladiinae (genus No. 2 unidentified)			I			I			
Orthocladiinae (genus No. 3 unidentified)			I						
Xenochironomus			I						
Stratiomyidae									
Eulalia					I				
Tabanidae									
Chrysops			I	I		I	I	I	C
Tabanus					I				
Tipulidae									
Gonomyia		I							
Tipula	I						I		
Collembola									
Isotomurus									I
Number of species	24	43	54	49	55	62	42	58	66

[a]The presence and degree of abundance of the species in the ponds are indicated by the following scale: I = 1 to 5, infrequent; C = 6 to 19, common; A = 20 and above, abundant.

to be relatively abundant in some ponds that are five years old and older. Mayflies occupy an important place in the food chain of aquatic communities because both the larvae and adults are eaten by fish. The most common genera encountered in the 1- to 3-year-old ponds were Notonecta, Laccophilus, Dineutus, Ablabesmyia, and Procladius. Of particular significance was the increase in the larval counts of the midge Procladius in the 2- and 3-year-old ponds. Results from bottom samples showed that larval counts of Procladius increased from 29 specimens in the 2-year-old ponds to 152 specimens in the 3-year-old ponds. In the 1976 study many of the Procladius larvae were found to exhibit abnormal mouthparts, especially those larvae from ponds formed five or more years ago.

Survey results revealed the presence of only two genera of medically important insects in the 1- to 3-year-old pond age category. Larvae of Palpomyia (Ceratopogonidae), sometimes called biting midges or punkies, were relatively abundant in the 2- and 3-year old ponds. Because of their bloodsucking ability, the adults of Ceratopogonidae can be serious pests along margins of streams and lakes. Two specimens of Chrysops (deer fly) were found in the 3-year-old ponds. Chrysops, which are persistent biters of man and livestock, are potential vectors of tularemia.

The data in Table 3 show that the 5- to 7-year-old ponds produced a wide diversity of insect taxa. Data from surveys of the 5-, 6-, and 7-year-old ponds yielded 49, 55, and 62 insect taxa, respectively. The dominant genera and species in the various insect orders, on the basis of frequency in collected samples, were Callibaetis, Hexagenia munda elegans, Enallagma basidens, Gomphys exilis, Trepobates, Dineutus, Berosus m. aculiatus, Sialis, Palpomyia, Ablabesmyia, Chironomus, Polypedilum, and Procladius.

Three insect genera of public health importance were recovered in dredge samples from the 5-, 6-, and 7-year-old ponds. Larval specimens of the very small biting gnat, Palpomyia, were abundant in the ponds, especially in samples from the 5-year-old ponds. A total of six larval specimens of the genus Chrysops was found in the 5- and 7-year-old ponds. No Chrysops larvae were detected in samples from the 6-year-old ponds. One larval specimen of Tabanus (horse fly) was found in samples from the 6-year-old ponds. Both deer flies and horse flies are fierce biters of man and livestock and may cause transfer of blood-inhabiting pathogenic organisms to man and animals (Jones 1964).

Data from benthic and surface samples in the 10-, 11-, and 12-year-old ponds showed this age group to have the greatest aquatic insect species diversity of the ponds studied. Sampling data from the 10-, 11-, and 12-year old ponds showed 42, 58, and 66 insect taxa, respectively. The most common genera and species were Hexagenia munda elegans, Enallagma aspersum, Gomphus exilis, Trepobates, Beunoa, Laccophilus maculosus, Dineutus, Ablabesmyia, Chironomus, Polypedilum, and Procladius. Midge larvae, Procladius, were the most abundant immature aquatic insects collected. This is of particular significance since many of the larvae in this midge group in the 10-year-old ponds were found to possess the mouthpart abnormality mentioned earlier. The genus characteristically

has a 5-toothed ligula. Many of the larvae examined from these older ponds had three to six ligular teeth, which were bifid, crooked, or otherwise asymmetrical. A special project has been established to study this unusual abnormality and to determine whether it might in some way be related to water quality.

Data from the 10-, 11-, and 12-year-old ponds showed a paucity of insects of medical importance, both in species composition and abundance. Larvae of the biting midge Palpomyia were found in small numbers in the 11- and 12-year-old ponds, but only one specimen was detected in samples from the 10-year-old ponds. Records from the 12-year-old ponds showed a total of 16 Chrysops larvae.

Adult Tabanidae Collections

No adult specimens of the family Tabanidae (horse flies and deer flies) were collected during the 1977 and 1978 seasons. However, several adults were collected from inside a parked sedan car located near the strip mine study ponds in 1976. These biting insects constitute one of the most annoying groups of bloodsucking insects that attack livestock and man. The eggs are laid in masses on vegetation extending over the water surface or in emergent vegetation, where the larvae can develop in water or damp soil. Most species of horse flies are strong fliers and have a flight range of several kilometers from the larval habitat. Very few tabanid larvae were detected in the benthic samples from the study ponds because a concerted specialized effort is required to collect them from pond margins. However, the strip mining occurs over an extensive area, and many ponds and wet areas are found which are considered the most likely source of production for those that were collected. Twenty-three adult specimens of tabanids, representing two genera, were collected in 1976; they included Hybomitra trispilus (1), Tabanus cheliopterus (2), Tabanus melanocerus (1), Tabanus nigripes (2), Tabanus sparus milleri (2), Tabanus fulvulus pallidescens (1), and Tabanus fulvulus (14).

Woody and Herbaceous Vegetation

A total of 69 plant species has been identified from the nine ponds during the study period. These are categorized in Table 4, according to their habitat zone, as submersed, emergent, wetland, or terrestrial.

The submersed vegetation consists of those plants that are rooted in the substrate, but have emergent inflorescences. The emergent species include plants that are firmly rooted in the substrate and have vegetative structures that extend above the water surface. The wetland species include plants growing in the transition zone just above the waterline in soils that are continually or seasonally saturated. Those plants growing above the transition zone in unsaturated soils are classified as terrestrial.

Potamogeton diversifolius was the dominant submersed species found in ponds more than one year old. Two other submersed species, Potamogeton

TABLE 4. LIST OF VASCULAR PLANT SPECIES AND MACROSCOPIC ALGAE ASSOCIATED WITH STRIP MINE PONDS OF VARIOUS AGES IN MARION COUNTY, ALABAMA[a]

Plant taxon	Age category of ponds[b]								
	1	2	3	5	6	7	10	11	12
Submersed									
Chara sp.					1				1
Potamogeton diversifolius		1	6	5	5	7	2	3	3
Potamogeton pusillus		1				2			
Emergent									
Eleocharis acicularis								1	
Eleocharis engelmannii								1	1
Eleocharis obtusa			3	2	2	5	5	5	8
Juncus acuminatus				1	2		7	8	6
Juncus debilis						1			
Scirpus cyperinus			1	3	3	3	9	9	9
Sparganium americanum				1	1				
Typha latifolia	7	7	6	9	9	9	7	7	7
Wetland									
Aster pilosus	1	1	1	4	1	7	4	5	2
Bidens frondosa			2	6	9	9	6	9	8
Cyperus odoratus			3						
Echinochloa crusgalli	1	1	8	3	3	3	4	3	2
Eclipta alba				2	2	2			
Eupatorium coelestinum								2	1
Eupatorium perfoliatum									1
Eupatorium serotinum			1	7	7	6	2	2	5
Eupatorium sessilfolium									1
Fimbristylis autumnalis						1	1	1	1
Hypericum mutilum							1	1	1
Ludwigia alternifolia				3	3	3	3	3	4
Mikania scandens							3	3	3
Panicum dichotomiflorum	2	3	6	8	8	9	3	3	5
Panicum lanuginosum									3
Panicum microcarpon	2			2		1	1	3	
Panicum verrucosum							1	1	1
Panicum sp.		1			1				
Pluchea camphorata			1	3	3	4	2	2	3
Polygonum hydropiperoides									1

TABLE 4 (continued)

Plant taxon	Age category of ponds[b] 1	2	3	5	6	7	10	11	12
Polygonum lapthifolium	2	2	6	1	1	3			
Polygonum pennsylvanicum	5	5	6	1	1		1	1	
Polygonum punctatum				1	1	2	2	2	1
Populus deltoides	1	1	3						
Salix nigra	6	3	5	9	9	9	9	9	8
Terrestrial									
Acer rubrum					1			1	1
Ambrosia artemisifolia			2	3	3	2	5	5	2
Andropogon virginicus	5	5	4	5	5	5	6	6	6
Aristida dichotoma	1	1					3	3	4
Aristida oligolantha			1						
Cassia nictitans				3	3	3	3	3	4
Chenopodium album				1	1			1	
Chenopodium ambrosioides	3	3	1						
Desmodium perplexum							1	1	
Digitaria ischaemum	1	1	5	2	2	7	4	4	3
Diodia teres	1	1		5	5	4	7	7	3
Diospyros virginiana				1	1	1			
Erechtites hieracifolia	3	3					6	6	1
Erianthus alopecuroides									1
Eupatorium compositifolium				2	2	1	6	4	1
Iva annua	2	2	8			1	2	2	1
Lespedeza cuneata				5	5	7	7	8	6
Lespedeza hirta							1	1	
Lespedeza striata	7	7	8	3		1	5	2	6
Lobelia puberula							2	2	2
Lonicera japonica									1
Oxalis sp.							1	1	1
Paspalum bosicianum							3	3	2
Paspalum dilatatum						1			
Phytolacca americana	6	6	1			3			1
Pinus virginiana	1	1							
Plantago aristata	1	1							
Polypremum procumbens							1	1	1
Pyrrhopappus carolinianus					1			1	
Rubus sp.				1	1	2			
Setaria geniculata				1	1		1	1	
Solidago sp.			1			1			1
Xanthium strumarium			1			1	1	1	

[a]Each number represents the number of sampling stations from which a species was present out of nine total stations.

[b]Each age category (e.g., 1-year-old ponds) contains three ponds, each of which contains three sampling stations.

pusillus and the macroscopic alga Chara, were also found in a limited number of ponds that were more than five years old. Eight emergent species have been recorded, with Typha latifolia, Scirpus cyperinum, Eleocharis obtusa, and Juncus acuminatus being the most common. Twenty-five wetland genera or species were found, the most abundant being Polygonum spp., Panicum spp., Eupatorium spp., Echinochloa crusgalli, Aster pilosus, Bidens frondosa, Ludwigia alternifolia, Pluchea camphorata, and Salix nigra. Many of the 33 terrestrial species identified during this study are common plants that invade disturbed sites. Since they seldom contribute to the mosquito breeding habitat, they will not be discussed in detail.

Newly formed ponds (one year old) were sparsely colonized and the macrophytes present were primarily wetland and terrestrial species common to disturbed sites. No submersed species and only one emergent species (Typha latifolia) were noted to colonize these ponds. Wetland species common to the newly formed ponds include Polygonum pennsylvanicum and Salix nigra. By the second year, two pondweeds (P. diversifolius and P. pusillus) had become established. Taxa established by the third year include two emergent species (Scirpus cyperinus and Eleocharis obtusa) and several wetland species (Pluchea camphorata, Bidens frondosa, Cyperus odoratus). S. scirpus, P. diversifolius, and P. pusillus provide a very favorable habitat for permanent pool mosquito species. While these species are undesirable from the standpoint of mosquito production, the two pondweeds (P. diversifolius and P. pusillus) are documented as a food source for waterfowl. Additional genera found in the older ponds (5 to 7 and 10 to 12 years) are Eleocharis spp., Juncus spp., Panicum spp., and Eupatorium spp.

Species diversity increased as the ponds became older. Twenty species were found in the 1-year-old ponds, compared with 45 species in the 12-year-old ponds. Because no discernible patterns of species replacement have been observed, the increase in species diversity represents the addition of species to previous vegetation.

Water pH

The average monthly water surface pH readings for each study pond group for the 1976, 1977, and 1978 growing seasons are given in Table 5. In general, the pH of the water in all the ponds is within the tolerance ranges that can support a large number of species of both plants and animals. This high pH value of the water in the strip mine ponds is most likely due to the large content of alkaline materials in the overburden. The 11-year-old ponds had a lower seasonal pH range than the other pond groups. The seasonal pH range of the water in the 1-, 2-, and 3-year-old ponds does not appear to differ significantly from that in the six older ponds.

TABLE 5. RESULTS OF MONTHLY MONITORING IN THREE CONSECUTIVE YEARS OF FOUR PHYSICAL PARAMETERS OF NINE COAL STRIP MINE PONDS IN MARION COUNTY, ALABAMA, APRIL - OCTOBER 1976, 1977, AND 1978

Pond age (y)	April	May	June	July	August	Sept.	Oct.	Seasonal range
				Average monthly pH				
1	7.3	7.5	7.4	8.1	8.1	7.5	7.4	6.4 - 8.7
2	7.7	8.1	7.4	7.3	7.6	7.4	7.6	6.2 - 8.5
3	6.7	7.2	6.7	6.8	8.3	8.0	7.8	6.0 - 8.6
5	7.2	7.4	7.2	7.4	6.6	7.6	7.6	5.7 - 8.9
6	7.2	7.4	7.9	7.3	7.1	7.1	7.6	5.7 - 8.9
7	6.7	6.3	6.8	6.7	7.4	8.0	8.0	5.8 - 9.0
10	6.8	6.9	6.7	6.7	7.1	6.3	6.6	5.9 - 8.2
11	7.1	6.7	7.0	7.0	6.2	6.2	7.3	5.0 - 8.3
12	6.6	7.0	6.3	7.1	7.2	8.0	7.3	5.3 - 8.6
				Average monthly DO (ppm)				
1	9.9	10.1	9.5	8.8	9.3	9.2	12.0	8.1 - 12.2
2	10.5	9.7	8.7	8.1	8.8	9.3	11.1	7.6 - 12.4
3	10.0	9.7	9.3	8.2	8.9	10.4	11.1	7.6 - 13.8
5	10.3	9.6	10.1	8.1	10.0	10.2	12.2	6.4 - 14.1
6	10.5	10.1	10.3	8.1	9.6	9.2	10.3	7.4 - 11.8
7	9.6	9.5	9.5	8.6	8.9	10.4	10.1	4.1 - 12.6
10	9.6	10.5	9.1	8.3	8.3	7.4	11.7	6.0 - 12.6
11	9.7	9.3	8.7	8.5	8.6	8.7	10.8	7.2 - 11.7
12	9.1	9.8	8.9	8.9	9.1	9.3	11.3	7.4 - 12.4
				Average monthly temperature (@C)				
1	23	23	28	30	29	26	12	9 - 31
2	23	27	30	29	32	25	16	13 - 33
3	20	21	23	29	27	26	16	14 - 30
5	19	27	28	33	29	26	14	13 - 42
6	24	27	30	31	32	27	17	17 - 33
7	21	20	26	26	25	26	15	10 - 30
10	26	23	28	28	29	26	13	8 - 31
11	27	27	31	31	29	28	18	15 - 34
12	18	21	22	28	24	26	15	12 - 29
				Average monthly conductivity (mmhos/cm)				
2	--	--	496.7	553.9	593.3	487.8	294.5	150 - 1000
3	283.8	275.0	298.0	349.4	367.8	269.0	307.8	27 - 700
6	--	--	641.7	602.2	580.0	487.5	359.5	195 - 1400
7	513.8	350.6	531.7	550.0	546.7	392.2	450.6	27 - 1150
11	--	--	85.2	78.9	76.1	60.0	48.9	20 - 160
12	54.4	57.5	49.4	67.2	62.2	69.9	56.7	15 - 170

Conductivity and Salinity

The data in Table 5 show that the water conductivity recordings in the 11- and 12-year-old ponds were significantly lower than those in the 2-, 3-, 6-, and 7-year old ponds. Water in the 6-year-old ponds had the highest conductivity recordings, with a seasonal range of 195 to 1400 mmhos/cm. The high conductivity reading in the pond water probably resulted from the buildup of electrolytes dissolved in water as a result of weathering of the adjacent spoil, which consists mainly of exposed rock. All the ponds showed an absence of salinity.

Dissolved Oxygen

Table 5 also summarizes the results of the dissolved oxygen determinations in each of the nine study ponds. These determinations indicate that no ecologically significant differences in the dissolved oxygen content occurred among the ponds. Some of the elevated dissolved oxygen readings in ponds five years old or older were likely influenced by colonies of P. diversifolius, which could have increased the midday dissolved oxygen content. However, much of the dissolved oxygen in the ponds, especially in the 1-, 2-, and 3-year-old ponds, is probably derived from the atmosphere by surface water agitation caused by wind and wave action.

Water Temperature

The average water temperature for each study pond is shown in Table 5. The variable temperature readings in the ponds were attributed to the inflow of ground water. Some differences occurred between the monthly temperature readings recorded in the different pond age categories, but these small variations could have resulted from climatic conditions.

Water Level

Seasonal water level deviations in the ponds for the 1978 season are graphically illustrated in Figure 2. The water recession in the study ponds for the 1978 season exhibited about the same pattern as in 1976 and 1977. However, drought conditions in May through July in 1977 caused abrupt water level recession in all the study ponds. This drop in water level was greatest in the 6-year-old ponds, with a drawdown of about 2 m. Heavy rainfall in the late summer of 1977 filled the 2-, 6-, and 11-year-old ponds to above the normal level, which inundated the terrestrial plant zone around the ponds. These extreme water level fluctuations could have influenced the quantity and quality of aquatic insect species collected in the sampling program, especially mosquitoes, because most of the likely vegetated habitats were dewatered early in the growing season.

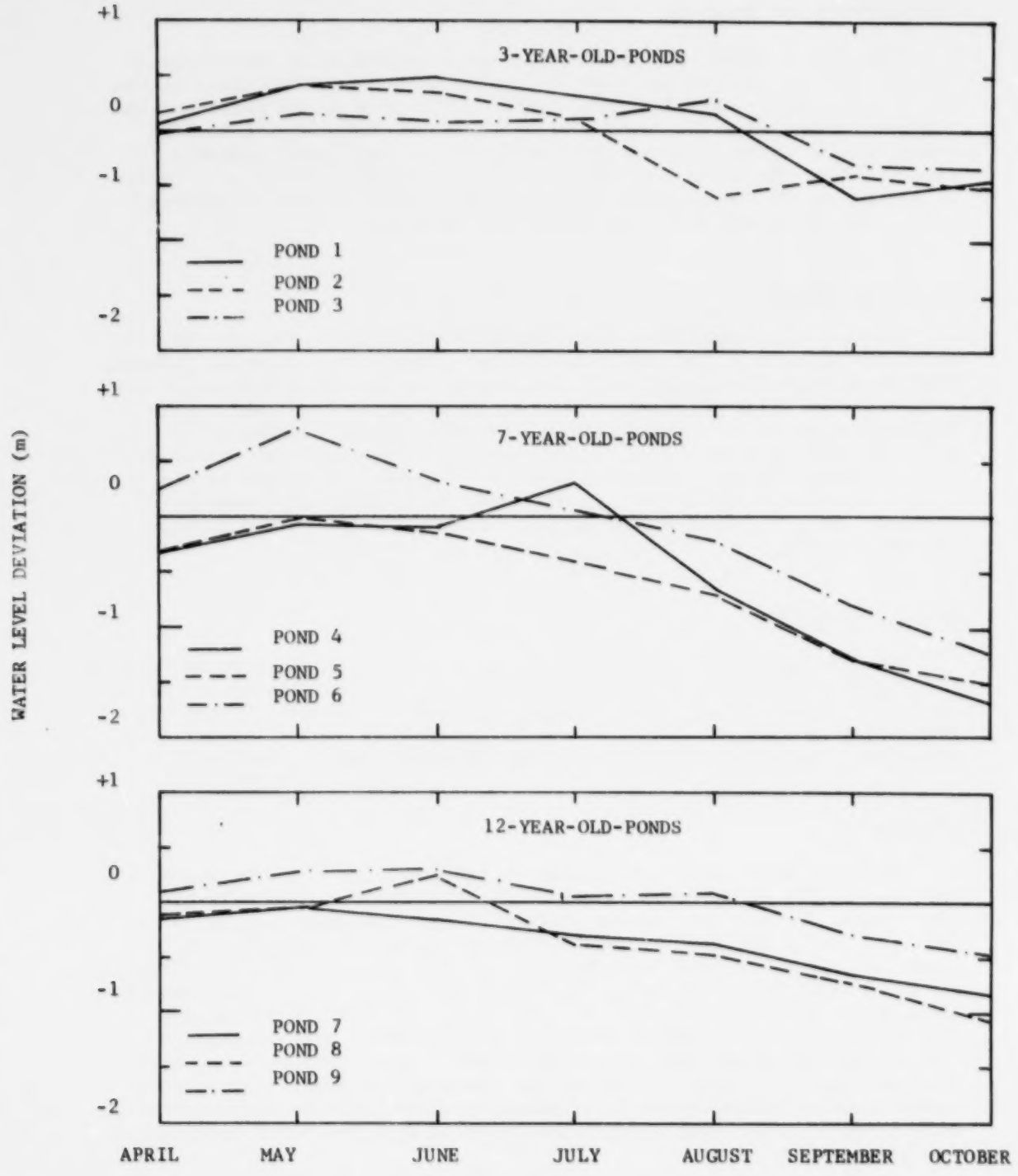

Figure 2. Water level fluctuations in the nine coal strip mine study ponds for the 1978 growing season.

Management of water levels to control mosquito production in ponds is a very effective naturalistic control measure. Ponds are usually filled during the wet period from late winter through spring, but water levels recede at the beginning of the dry season. This seasonal water level recession (Figure 2) coincides with the active breeding season for permanent pool mosquitoes, thus effectively controlling these types of mosquitoes. However, wide amplitudes of water level fluctuations that periodically expose large areas of shoreline, as occur in the 6-year-old ponds, can be very conducive to the production of floodwater mosquitoes. The floodwater species of mosquitoes generally deposit their eggs on the damp soil along vegetated shorelines that are intermittently flooded. A brood of floodwater mosquitoes can be produced if the water level in the pond first recedes enough to allow deposition of eggs and then is followed by sufficient rainfall to raise the water level again and inundate the eggs, causing them to hatch. However, results from soil samples collected from these dewatered pond margins showed a paucity of floodwater mosquito ova.

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